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STARBURST OUTFLOWS FROM NEARBY GALAXIES

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1. NGC 5461: The Sc I galaxy, M101, is renowned for the kpc-size "superassociations" of star clusters and HII regions that dominate its spiral arms. NGC 5461 is one of the brightest of these superassociations, rivaling the Large Magellanic Cloud in $H\alpha$ luminosity. Figure 1 shows this region in the light of $H\alpha$, as observed with the McGraw-Hill 1.3 m telescope (Waller 1989). Unlike its complicated neighbor, NGC 5462, the NGC 5461 superassociation is dominated by a single unresolved HII region of outstanding luminosity (~ 1000 Orion nebulae). Figure 1 also shows 3 plume-like features of diffuse ionized gas diverging from the brilliant core toward the South, Southeast, and East. Detailed examination of corresponding continuum images indicates that only the southern plume has any sort of stellar counterpart. The other plumes are clearly diffuse with no underlying hot stars. Seen in projection, the plumes extend for roughly 650 pc (for an adopted distance to M101 of 4.8 Mpc). An HI map with a resolution of $30''$ (700 pc) reveals a pronounced bulging on the southeast ("plume") side of NGC 5461 (Viallefond *et al.* 1981). Higher resolution mapping of the HI emission (using the VLA) as well as sensitive radial-velocity mapping of the diffuse $H\alpha$ emission (using Fabry-Perot interferometry or dense-pack multifiber spectroscopy) would greatly aid in the correct interpretation of this outflow candidate.

2. NGC 1569: Figure 2 shows this "posteruptive" Irr I galaxy in the light of $H\alpha$, as observed with the #1 0.9 m telescope at Kitt Peak (Waller 1989). Besides showing the peculiar "arm" noted by Zwicky (1971) and the filamentary extensions to the North and South (as noted by Hodge 1974), this image also reveals two arc-like features of diffuse ionized gas to the South. Both "arcs" are concentric with the bright center of the galaxy - where the super star clusters, A and B, are located. The inner arc ("Arc 1") appears to follow the same curve as the SW "arm" thus suggesting that the two features represent limb-brightened fragments of a vast superbubble that was blown out by a central starburst sometime in the past. The displacements of the "arcs" from the center of the galaxy are estimated to be 1.2 and 1.5 kpc respectively (assuming a distance of 2.2 Mpc and an orientation along the minor axis which is inclined 27° to the plane of the sky). The $H\alpha$ velocity field of de Vaucouleurs (1981) shows a strong gradient along the minor axis which, if due to outflowing motions along the minor axis, would imply outflow velocities of up to 90 km s^{-1} . The resulting kinematic ages for the "arcs" would be 13 and 16 Myr respectively. These crude estimates for the age of the nuclear starburst are well-matched with the age that Israel and de Bruyn (1988) estimate based on the last major injection of energetic electrons into the ISM. The mechanical energy required to create the superbubble is estimated to be $\sim 10^{54}$ ergs, or the equivalent of $\sim 10^3 - 10^5$ supernovae - depending on the coupling efficiency between the supernova energy and mechanical motions of the gas. A coherent ($\Delta t \leq 1 \text{ Myr}$) salvo of this many supernovae could have detonated in the nucleus without exceeding the supernova rate that Israel and de Bruyn (1988) estimate from their radio continuum measurements.

3. M82: As the classic "starburst galaxy," M82 displays all the luminous hallmarks of intense high-mass star formation and outflow activity (cf. Telesco 1988; Sofue 1988). The diffuse H α and x-ray emitting gas along the minor axis provides especially good evidence for a bipolar outflow of hot (10^7 K) gas which is shock heating the swept-up ISM to temperatures of $\sim 10^4$ K (Watson *et al.* 1984; Bland and Tully 1988). Figure 3a shows the H α emission within the disk and along the minor axis; Figure 3b shows the same field in the light of near-infrared [SII]($\lambda 9532$). Both figures are based on CCD images taken with the McGraw-Hill 1.3 m telescope (Waller 1989). The longer wavelength emission clearly shows a more extended morphology along the major axis. The morphological discrepancy is most likely due to the greater obscuration by dust suffered by the H α photons. Figure 3c shows the map of visual extinction that I derive from a pixel-by-pixel comparison of the [SII] and H α fluxes. The greatest extinctions are evident along an arc that includes two especially obscured regions on opposite sides of the bursting nucleus. The arclike morphology of the obscuration as well as the strong peripheral extinction can be attributed to a circumnuclear ring of dust that is highly inclined to the line of sight. This is akin to the "dusty chimney" picture that Nakai *et al.* (1987) proposed to explain the "spur-like structures" evident in their CO map. Alternatively, the arc could be tracing the remnant of a superbubble which burst towards the South. A recent high-resolution mapping of the HI in M82 (Yun, Ho, and Lo 1989) seems to corroborate the shell remnant scenario, in that the greatest concentrations of circumnuclear HI are to the Northeast and Northwest of the central starburst just beyond the obscuring arc. Although these comparisons do not lead to a well-defined morphology, they reinforce the picture of a circumnuclear pile-up of dust and gas ($M \sim 4 \times 10^8 M_\odot$) that has been shaped by the starburst and is now collimating the subsequent eruptions ($E \sim 10^{56}$ ergs).

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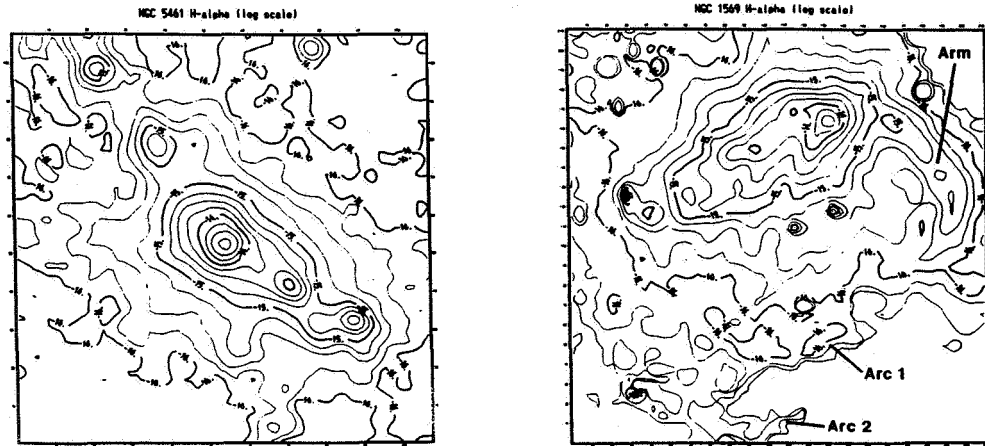


Figure 1. NGC 5461 in the light of H α . The field of view is $1.43' \times 1.43'$ ($2 \text{ kpc} \times 2 \text{ kpc}$ at a distance of 4.8 Mpc). The surface brightness is contoured in logarithmic intervals of 0.25 starting at $10^{-16} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ arcsec}^{-2}$. Low surface brightness "plumes" of ionized gas are evident, diverging from the brilliant core toward the South, Southeast, and East.

Figure 2. NGC 1569 in the light of H α . The field of view is $3' \times 3'$ ($1.9 \text{ kpc} \times 1.9 \text{ kpc}$ at a distance of 2.2 Mpc). The surface brightness is contoured in logarithmic intervals of 0.25 starting at $3.2 \times 10^{-17} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ arcsec}^{-2}$. The "arm" and "arcs" are diffuse features with no stellar counterparts.

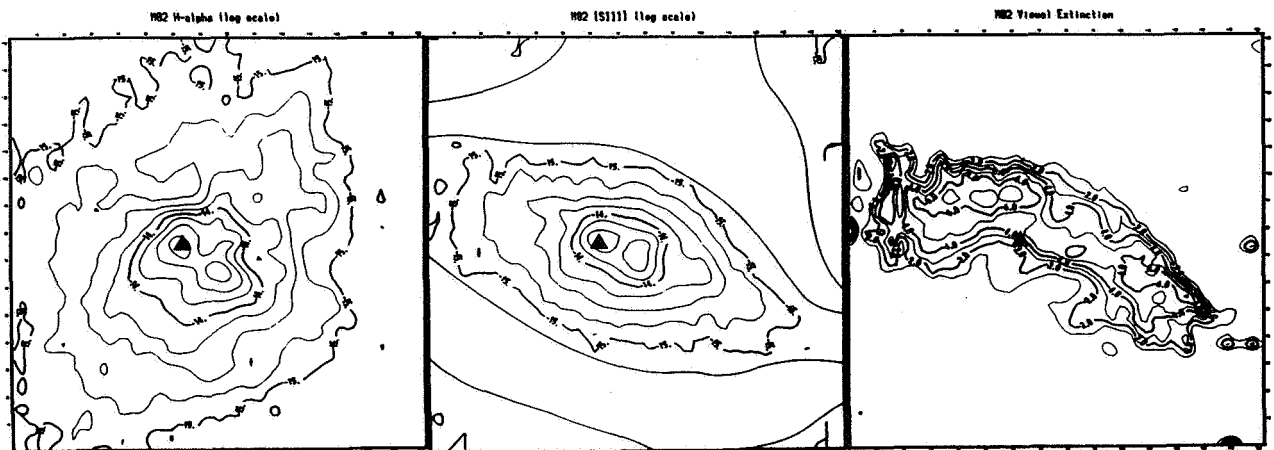


Figure 3. The H α emission from M82 (a); the corresponding [SIII] λ 9532 emission (b); and the visual extinction (c) as derived from the [SIII]/H α flux ratio. The field of view is $2' \times 2'$ ($1.9 \text{ kpc} \times 1.9 \text{ kpc}$ at a distance of 3.25 Mpc). The surface brightness maps are contoured in logarithmic intervals of 0.25 starting at $10^{-15} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ arcsec}^{-2}$ for the H α emission and $3.2 \times 10^{-16} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ arcsec}^{-2}$ for the [SIII] emission. The map of visual extinctions is contoured from 1.0 to 7.0 mag. in intervals of 1.0 mag. The filled triangle designates the position of the $2.2 \mu\text{m}$ stellar nucleus.